RESEARCH DEPARTMENT

The Performance of some American Convertors and Tuning Units for Television Reception in the U.H.F. Band

Report No. G.055

Serial No. 1954/31

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

KEY

CONVERTOR 1	Philco 200X External UHF Tuner
CONVERTOR 2	Mallory TV101 UHF Convertor
CONVERTOR 3	RCA Victor UHF Selector Model U70
TUNER 1	RCA KRK 25 Tuner Kit
TUNER 2	Standard Coil Products Tuner

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CONFIDENTIAL

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SUMMARY

The results of tests on some current American u.h.f. television convertors and tuning units are described. The performance of the better types is extremely good; the noise factor is low, and the drift of the local oscillator frequency after switching on is not excessive in view of the current American practice of inter-carrier reception of the sound signal.

The results are discussed in terms of the requirements for a satisfactory television service.

1. INTRODUCTION

Until September 1952 television broadcasting in the United States was carried out only in the v.h.f. band. All current receivers could be used on any one of twelve v.h.f. channels, each occupying a bandwidth of 6 Mc/s, the vision carrier frequencies lying between 55·25 and 83·25 Mc/s (Channels 2–6) and between 175·25 and 211·25 Mc/s (Channels 7–13). Only some of these channels are, of course, in use in any one locality.

The introduction of television broadcasting in the u.h.f. band 470–890 Mc/s (Channels 14–83) led to a demand for receivers to work in the new band. This was met in the first place by the use of convertors external to the v.h.f. receiver; these were designed to change the frequency of the u.h.f. transmission to that of one of the v.h.f. channels not used locally. Later, tuning units were designed which could either be incorporated in new receivers, or could replace the tuning unit in existing v.h.f. sets. In some cases the same basic design is adapted either as a tuning unit or as a convertor.

In the case of v.h.f. receivers incorporating a turret tuner with replaceable strips (one corresponding to each channel) it was possible to remove the v.h.f. strips not in use and to replace them by strips for reception of the local u.h.f. station.

Performance tests on three convertors and two tuning units, thought to be typical of those at present in general use in the United States, are described below.

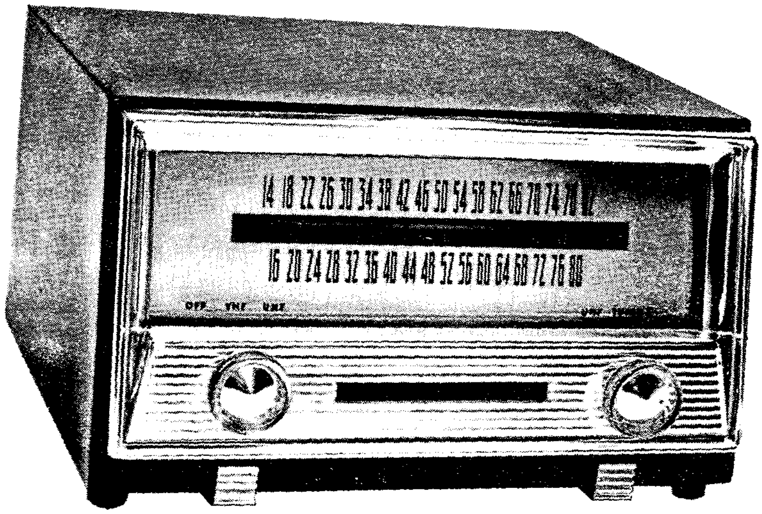


Fig. 1 - Convertor I. External View.

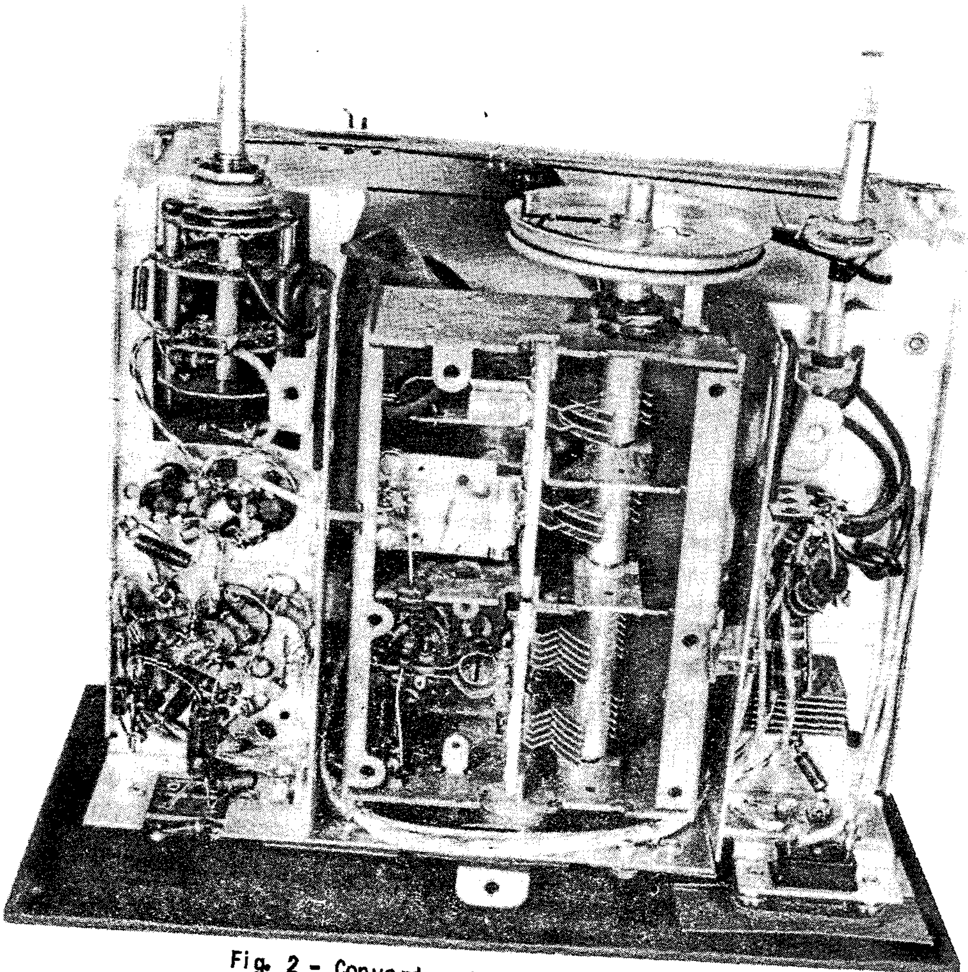


Fig. 2 - Convertor I. Internal View.

2. U.H.F. CONVERTORS.

2.1. General

Convertors are usually contained in small cabinets of wood or plastic; they are provided with a tuning control and a three-position switch labelled "OFF" "VHF" and "UHF". When the switch is in the centre position, the v.h.f. receiver operates normally; with the switch in the position marked "UHF" and the receiver set to the appropriate v.h.f. channel, the convertor permits selection of the required u.h.f. station, the appropriate channel number being indicated on the tuning dial. The rear panel of the cabinet is fitted with three pairs of terminals to which are connected the v.h.f. aerial, the u.h.f. aerial and the receiver input. A mains socket is also fitted on this rear panel, the ON/OFF knob being used to control the power supplies to both the receiver and the convertor.

The bandwidth of the convertor is made sufficiently wide to cover two adjacent channels, the output frequency being 60 Mc/s in some cases and 82 Mc/s in others. The v.h.f. receiver is therefore set to one of the Channels 2 and 3, or one of the Channels 5 and 6, depending on the convertor output frequency. Frequency allocations in the United States are such that no one area has services operating on both Channels 2 and 3 or on both Channels 5 and 6. The v.h.f. receiver is therefore set to the appropriate channel not used locally, and the problem of direct "break-through" into the v.h.f. set is thereby avoided.

Signal-frequency amplification in the u.h.f. band is not used in any of the convertors or tuning units at present in use in the United States; although valves for this purpose are available it is understood that their cost is high and their life short. The mixer is usually a crystal diode and is preceded by two coupled tuned circuits; these are ganged with a similar circuit controlling the frequency of the oscillator, and tracked to maintain a good performance over the u.h.f. band. In current convertors the oscillator is invariably a 6AF4 triode valve which was specially developed for the purpose; it operates at a fundamental frequency which is lower than that of the signal by the frequency of the v.h.f. channel used as the first intermediate frequency. Amplification at this intermediate frequency is usually provided by a double triode such as the 6BQ7, connected as a cascode, although one of the units tested employs a pentode amplifier.

2.2. Performance tests

2.2.1. Convertor 1 (Figs. 1 – 4)

The price of this convertor is $75, or $50 when supplied as a kit of parts for modification to v.h.f. receivers; it is contained in a mahogany cabinet. The circuit diagram is shown in Fig. 3. Two signal-frequency circuits and the oscillator circuit are tuned by ganged variable condensers; the former incorporate inductances and capacitors centre-tapped and balanced with respect to earth. The convertor is designed to give an output either on Channel 2 or Channel 3.

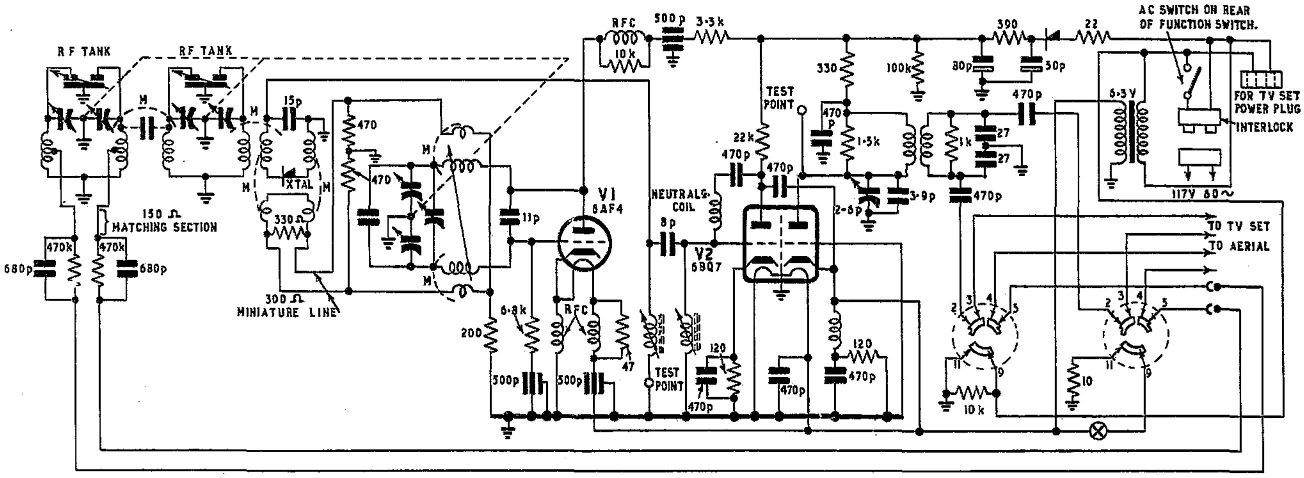


Fig. 3 - Convertor I. Circuit Diagram.

Size:	$9\frac{1}{4}$ in. × $8\frac{3}{4}$ in. × $5\frac{1}{2}$ in. (23 cm × 22 cm × 14 cm)	Conversion gain:	8 dB at 470 Mc/s 8 dB at 600 Mc/s 3 dB at 850 Mc/s
Weight:	6 lb (2·7 kg)	Overall bandwidth: (for loss of 6 dB)	9·2 Mc/s
Power supplies:	13 watts at 115 V, 60 c/s	Valves:	6AF4 Oscillator CP2 Crystal diode mixer 6BQ7 Cascode i.f. amplifier Metal rectifier for anode supplies
Aerial input impedance:	300 ohms		
Output impedance:	300 ohms		
Noise factor:	11 dB at 470 Mc/s 15 dB at 600 Mc/s 15 dB at 775 Mc/s 18 dB at 850 Mc/s		

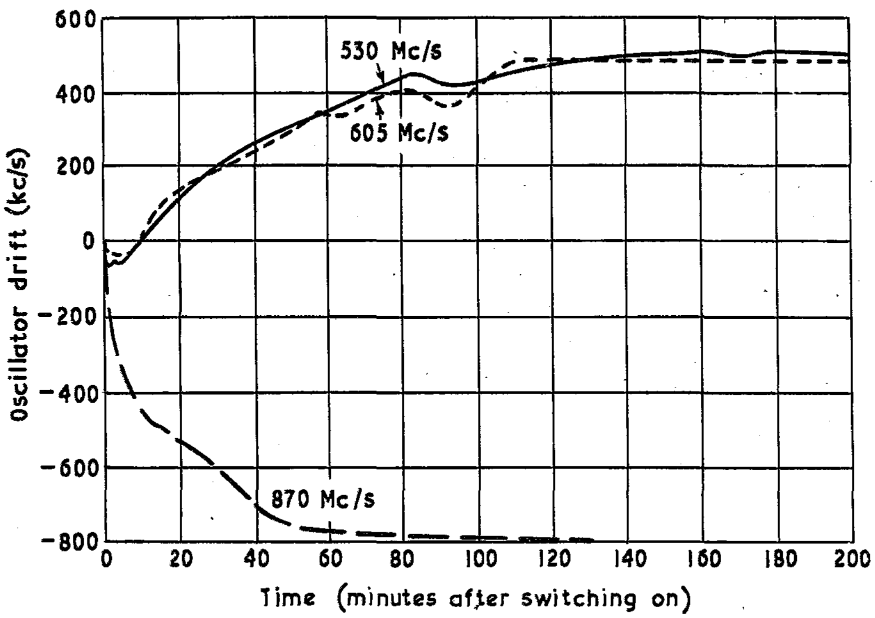


Fig. 4 - Convertor I. Oscillator Drift.

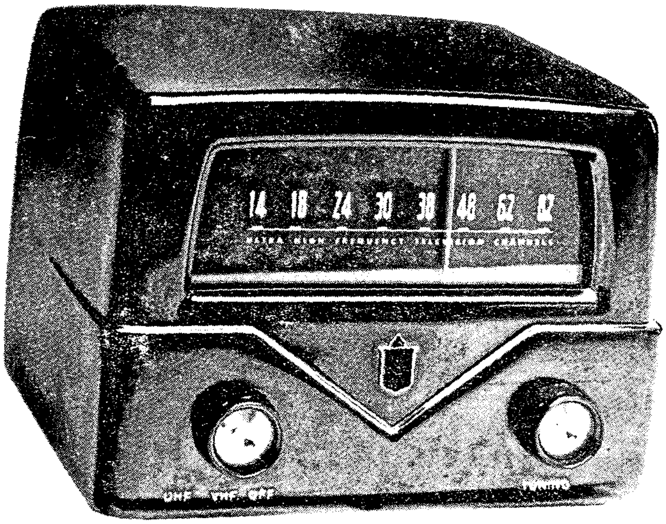


Fig. 5 - Convertor 2. External View.

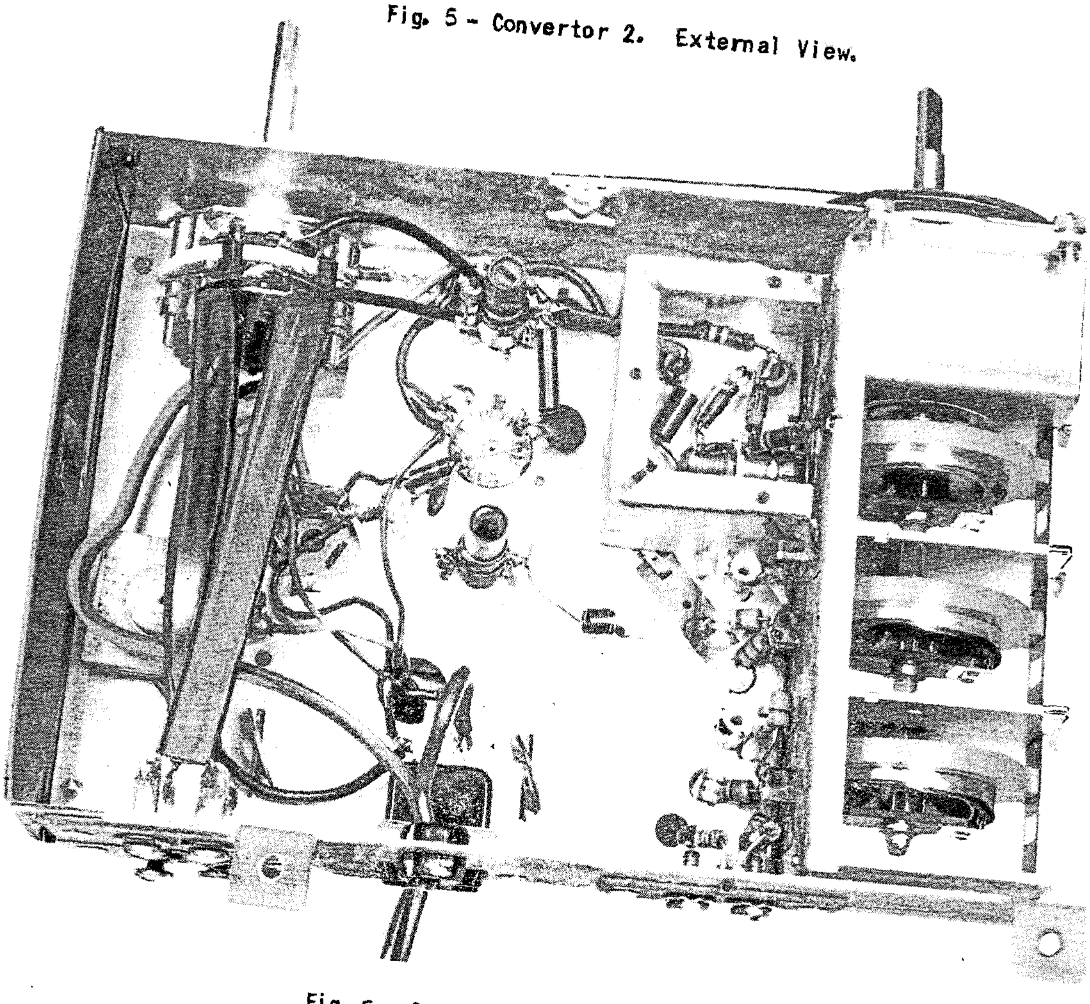


Fig. 6 - Convertor 2. Internal View.

2.2.2. Convertor 2 (Figs. 5 – 8).

The price of this convertor is approximately $25; it is contained in a bakelite cabinet and designed for use with a receiver tuned to either Channel 5 or 6. The circuit diagram is shown in Fig. 7. The two signal-frequency circuits and the oscillator tuning circuits are formed by a three-section "UHF Inductuner", seen on the right of Fig. 6. Each circuit consists of a parallel strip transmission line with a sliding short-circuit for tuning purposes; the position of the short circuit is adjusted by means of a radial arm attached to a spindle. The transmission lines are shaped to form an arc of a circle.

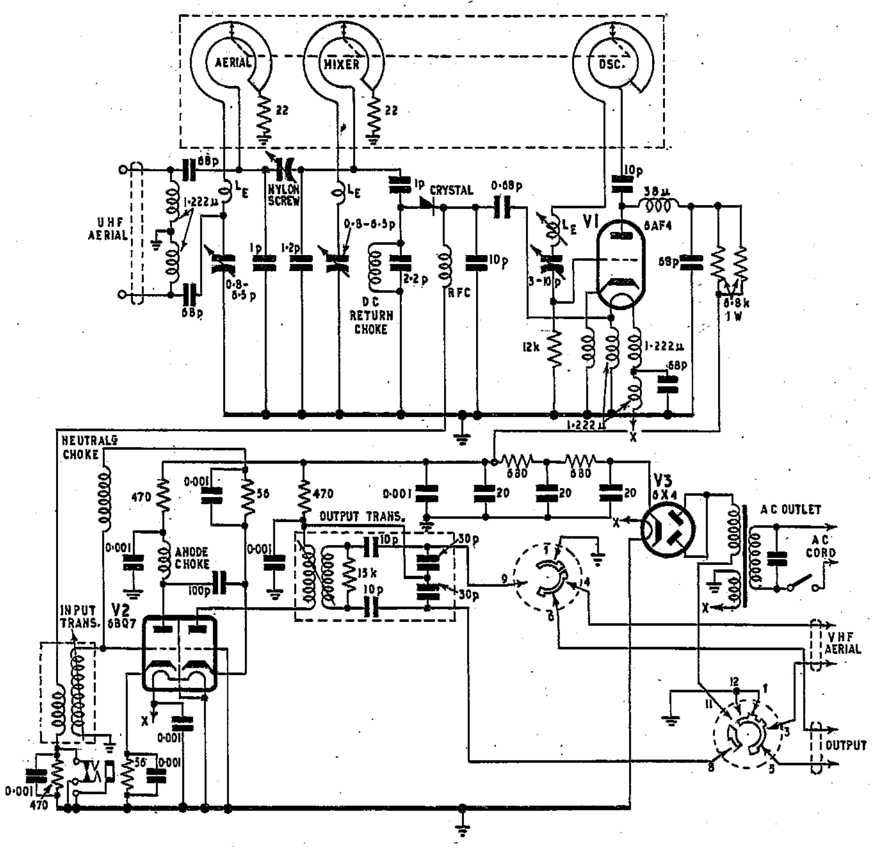


Fig. 7 - Convertor 2. Circuit Diagram.

Size:	9 in. × $7\frac{1}{2}$ in. × $6\frac{7}{8}$ in. (23 cm × 19 cm × 17 cm)	Conversion gain:	5 dB at 470 Mc/s 8 dB at 600 Mc/s 4 dB at 800 Mc/s
Weight:	$6\frac{1}{2}$ lb (3 kg)	Overall bandwidth: (for loss of 6 dB)	20 Mc/s
Power supplies:	17 watts at 117 V, 60 c/s	Valves:	6AF4 Oscillator IN72 Germanium diode mixer 6BQ7 Cascode i.f. amplifier 6X4 Rectifier
Aerial input impedance:	300 ohms balanced or unbalanced		
Output impedance:	300 ohms		
Noise factor:	> 19 dB at 470 Mc/s * 19 dB at 530 Mc/s > 19 dB at 850 Mc/s		

* 19 dB was the highest noise factor measurable with the equipment available

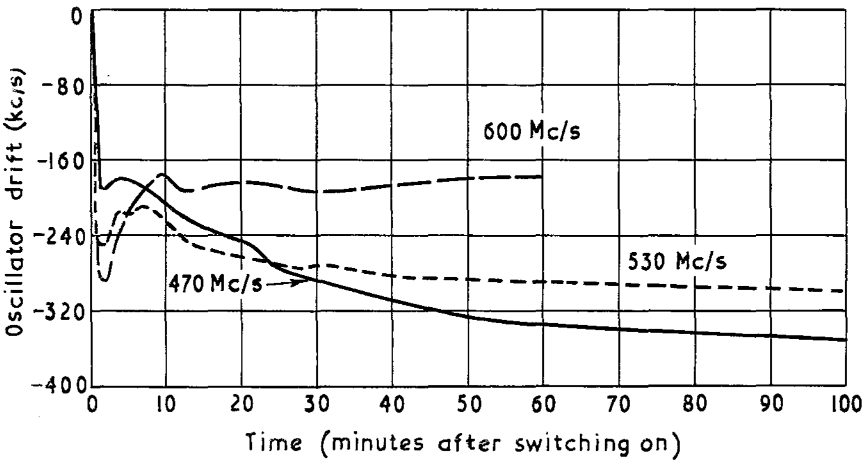


Fig. 8 - Convertor 2. Oscillator Drift.

2.2.3. Convertor 3 (Figs. 9 - 12)

This convertor is contained in a wooden cabinet; it is designed for use with a receiver tuned to either Channel 5 or 6. The circuit diagram is shown in Fig. 11. The two signal-frequency circuits are link coupled and tuned by variable capacity; the oscillator circuit is tuned by variable capacity and inductance. The i.f. amplification is obtained with two pentodes separated by a tuned transformer, the first pentode operating as a grounded-grid triode.

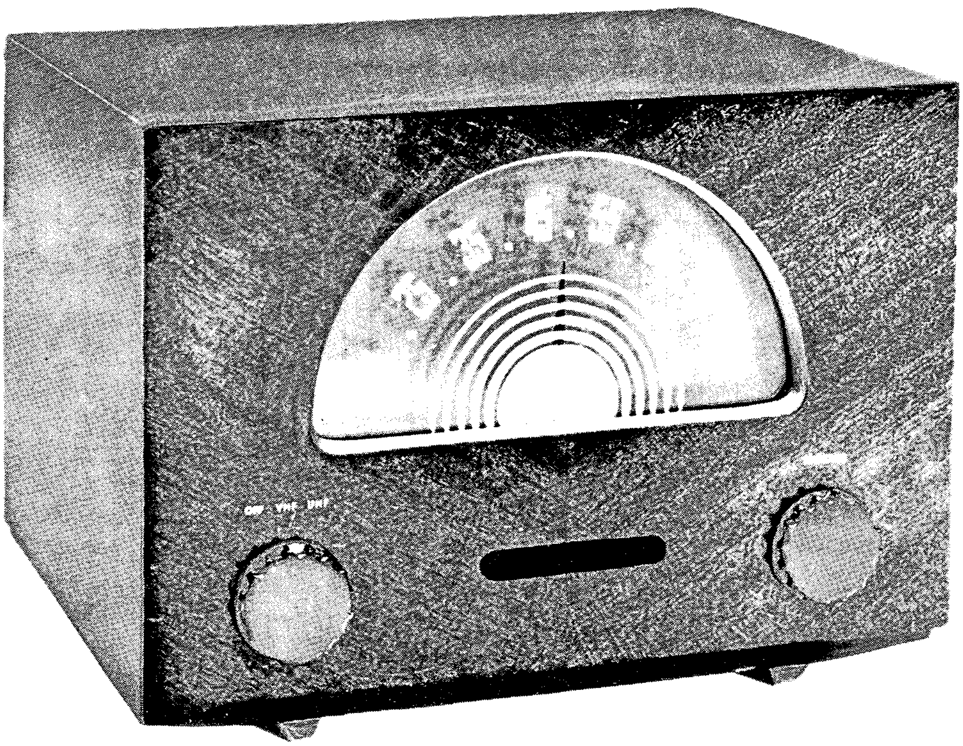


Fig. 9 - Convertor 3. External View.

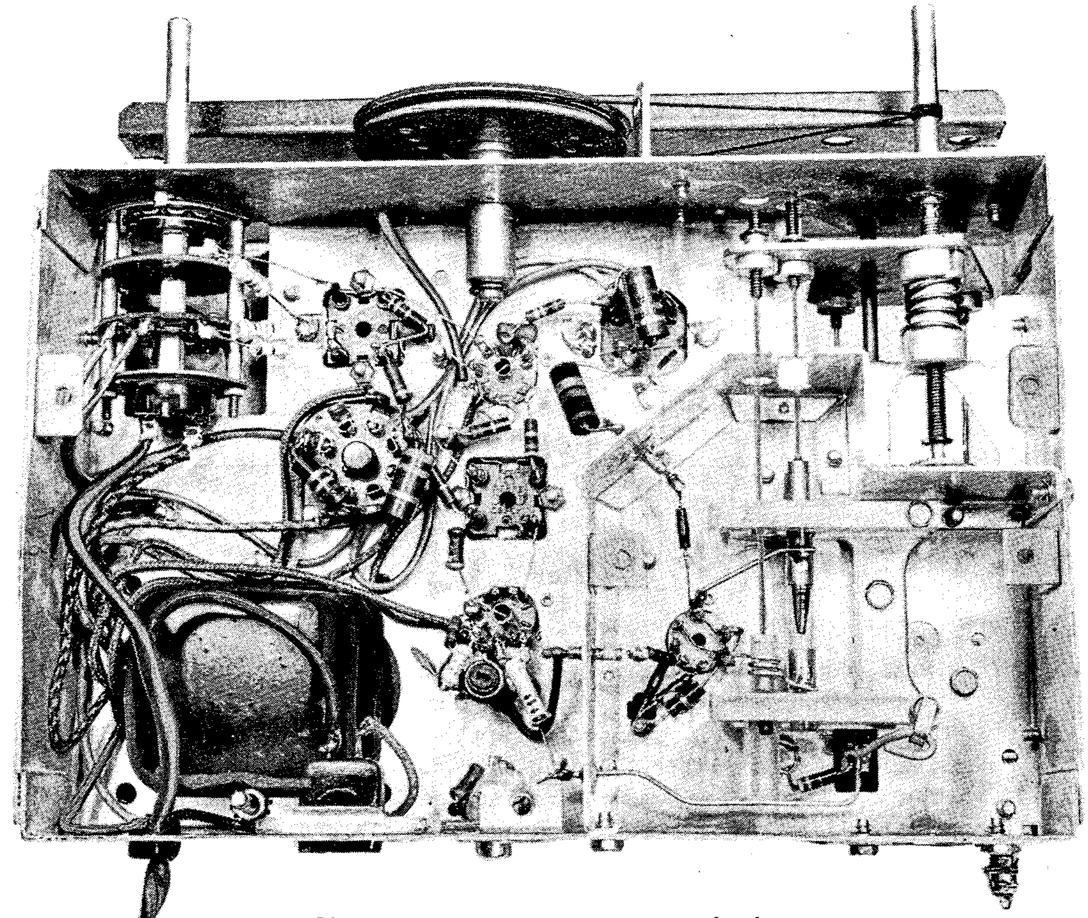


Fig. 10 - Convertor 3. Internal View.

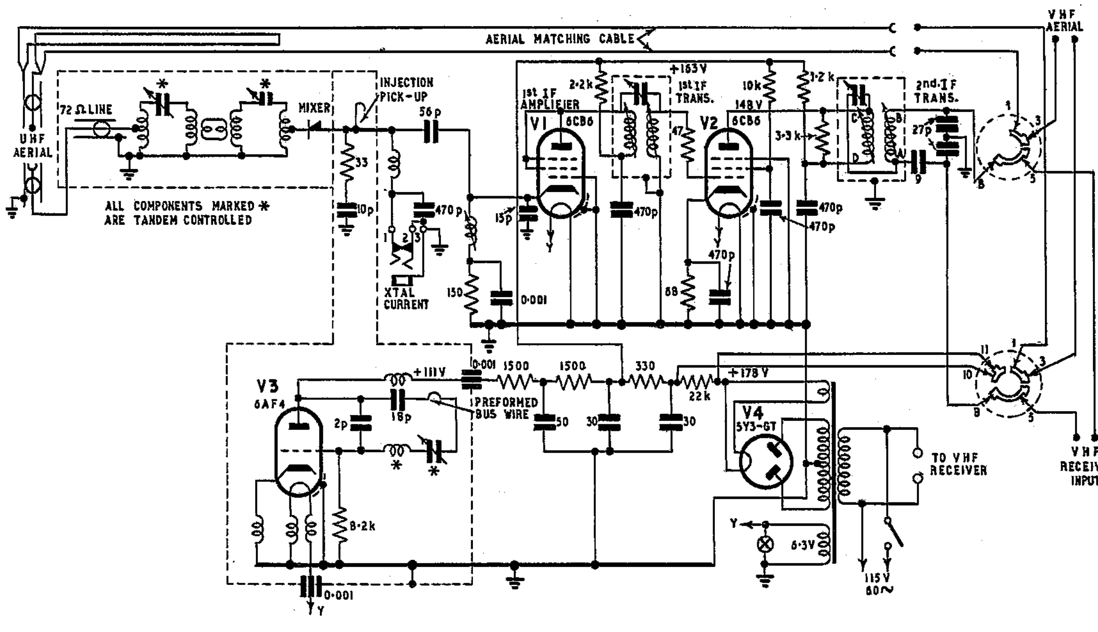


Fig. 11 - Convertor 3. Circuit Diagram.

Size:	11 in. × $9\frac{3}{4}$ in. × $8\frac{1}{4}$ in. (28 cm × 25 cm × 21 cm)
Weight:	10 lb (4·5 kg)
Power supplies:	40 watts at 115 V, 60 c/s
Aerial input impedance:	300 ohms balanced or 75 ohms unbalanced
Output impedance:	300 ohms balanced
Noise factor:	> 19 dB at 470 Mc/s > 19 dB at 600 Mc/s > 19 dB at 800 Mc/s
Conversion gain:	3 dB at 470 Mc/s 3 dB at 600 Mc/s 4 dB at 850 Mc/s
Overall bandwidth: (for loss of 6 dB)	21·5 Mc/s at 470 Mc/s 24·6 Mc/s at 600 Mc/s 17·5 Mc/s at 850 Mc/s
Valves:	6AF4 Oscillator IN82 Germanium diode mixer 6CB6 First i.f. amplifier 6CB6 Second i.f. amplifier 5Y3GT Rectifier

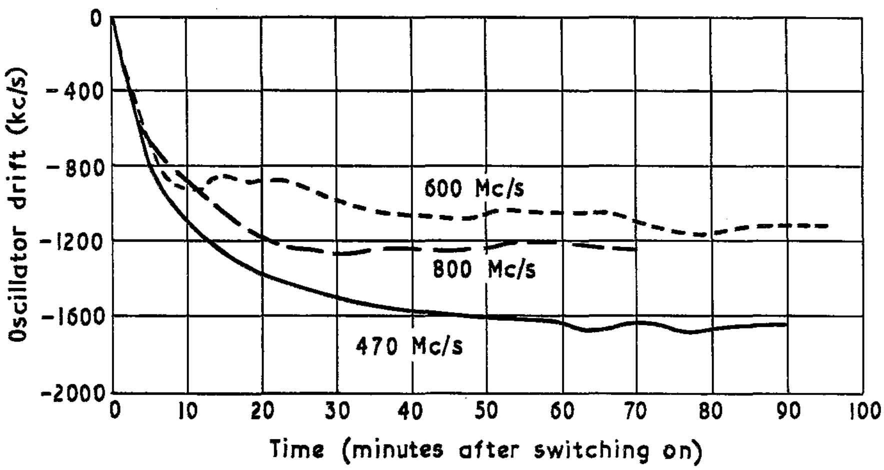


Fig. 12 - Convertor 3. Oscillator Drift.

3. U.H.F. TUNING UNITS.

3.1. General

U.H.F. tuning units are intended to be installed inside the v.h.f. receiver cabinet and to replace the existing signal-frequency and mixer circuits. They usually incorporate two u.h.f. tuned circuits, a crystal diode mixer and a cascode i.f. amplifier. The latter is fitted on the tuner unit to avoid unnecessary loss between the mixer and the first i.f. amplifier of the receiver.

Tuning units fall into two distinct classes, those which are continuously tunable, and those with switched pre-tuned circuits. The former are very similar to the convertors already discussed except that they feed direct into the receiver intermediate frequency amplifier. The switched type incorporates a turret containing removable strips, the pre-tuned circuits being connected to a row of contacts. Only a limited number of stations can therefore be received and these may be in the v.h.f.

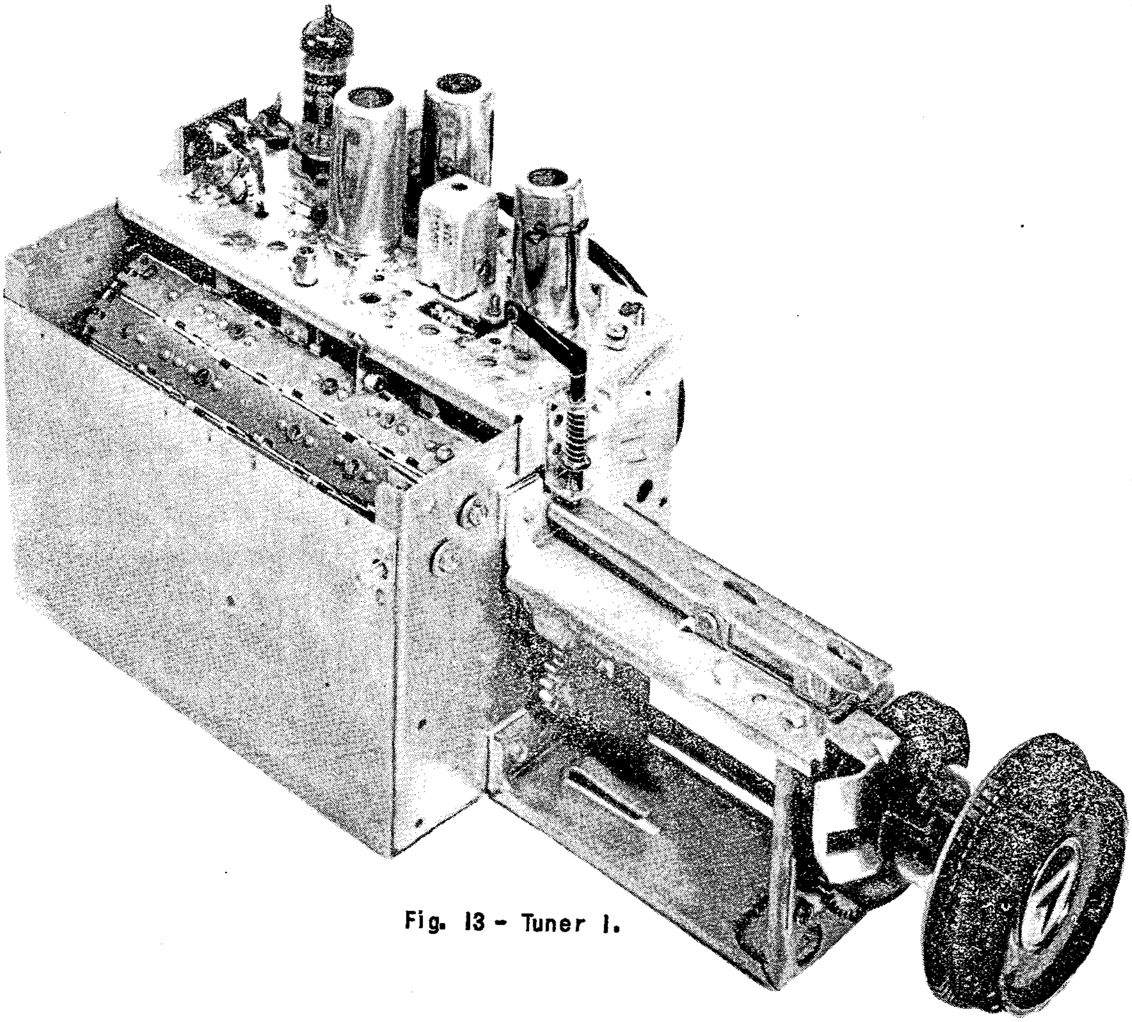
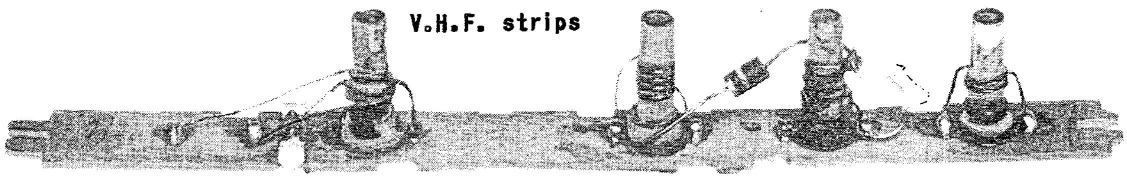


Fig. 13 - Tuner I.

V.H.F. strips



U.H.F. strips

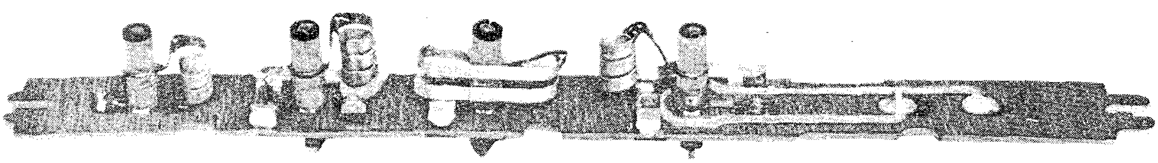


Fig. 14 - Tuner I. Channel strips

or the u.h.f. bands; of the two units described here, one has provision for reception of twelve channels and the other for sixteen channels. A cascode signal-frequency amplifier and a triode or pentode frequency changer are usually switched into circuit for reception of the v.h.f. channels.

A "fine tuning" control of the oscillator frequency is provided; the control is concentric with the channel selector switch.

3.1.1. Tuner 1 (Figs. 13 - 16)

The price of this tuner is approximately $45. The circuit diagram is shown in Fig. 15. It is designed for reception of sixteen channels; of the associated sixteen strips, four are normally for u.h.f. and twelve for v.h.f. reception, although unwanted v.h.f. strips can be replaced by additional u.h.f. strips if necessary. Strips can be easily changed after releasing a spring retaining clip; typical strips are shown in Fig. 14. When a u.h.f. strip is switched into circuit the signal frequency selectivity is provided by a triple tuned bandpass circuit formed by silver-plated strip coils and concentric tubular trimmer condensers. The mixer is a germanium crystal diode and the oscillator is a 6AF4 triode; the output of the mixer is amplified by a double-triode cascode circuit before being fed to the receiver i.f. amplifier.

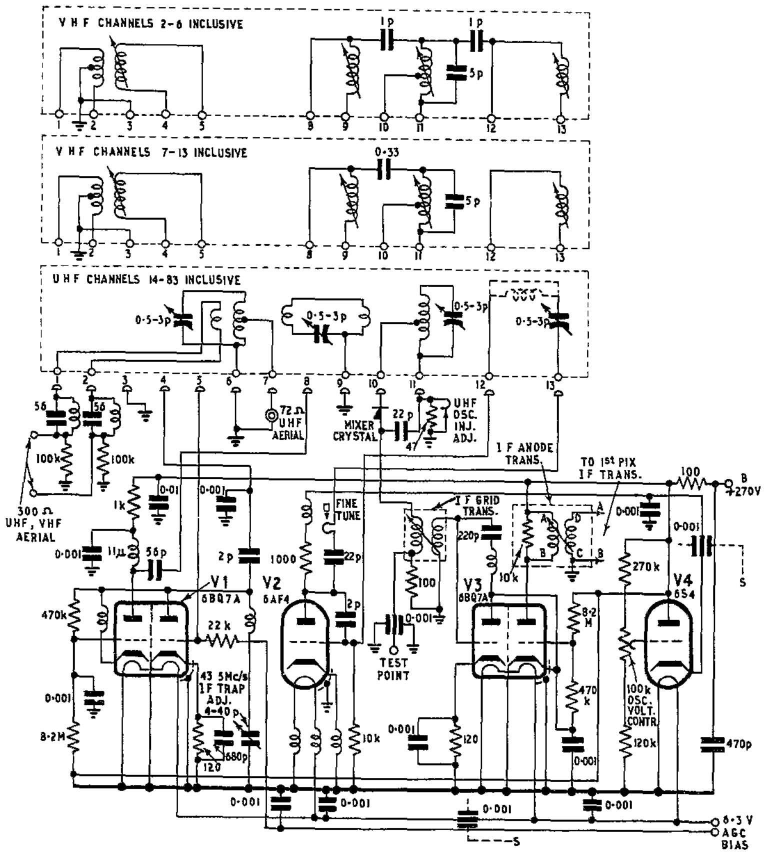


Fig. 15 - Tuner 1. Circuit Diagram.

When a v.h.f. strip is switched into position, the circuit consists of a cascode signal-frequency amplifier, a crystal diode mixer with a triode oscillator, and a cascode amplifier at an intermediate frequency of 41·25 Mc/s (sound carrier), the recommended standard in the United States. The manufacturer's published performance figures for this tuning unit are given in the Appendix; where a comparison is possible with the following results, the agreement is reasonably good.

Size:	$13\frac{3}{4}$ in. (neglecting drive spindle) × $5\frac{1}{2}$ in. × 8 in. (35 cm × 14 cm × 20 cm)
Aerial input impedance:	300 ohms (u.h.f. and v.h.f.) and 75 ohms (optional at u.h.f)
Noise factor:	6 dB at 55 Mc/s 12 dB at 575 Mc/s 15 dB at 695 Mc/s (u.h.f. strips for frequencies higher than 695 Mc/s were not available when the tests were made)
Conversion gain:	Voltage gain 28 at 55 Mc/s " " 2·5 at 575 Mc/s " " 2·5 at 695 Mc/s This conversion gain was measured with the unit feeding into a 75 ohm impedance whereas the unit is designed to feed into a step-up transformer in the i.f. amplifier of the receiver. Figures given by the manufacturer under these conditions are quoted in the Appendix and will be found to be rather higher than those given above.
Overall bandwidth: (for loss of 6 dB)	16 Mc/s at 575 Mc/s 13 Mc/s at 695 Mc/s
Valves:	6AF4 Oscillator 6BQ7A Cascode amplifier, used on v.h.f. only IN82 Germanium diode mixer 6BQ7A Cascode i.f. amplifier 6S4 Series voltage regulator

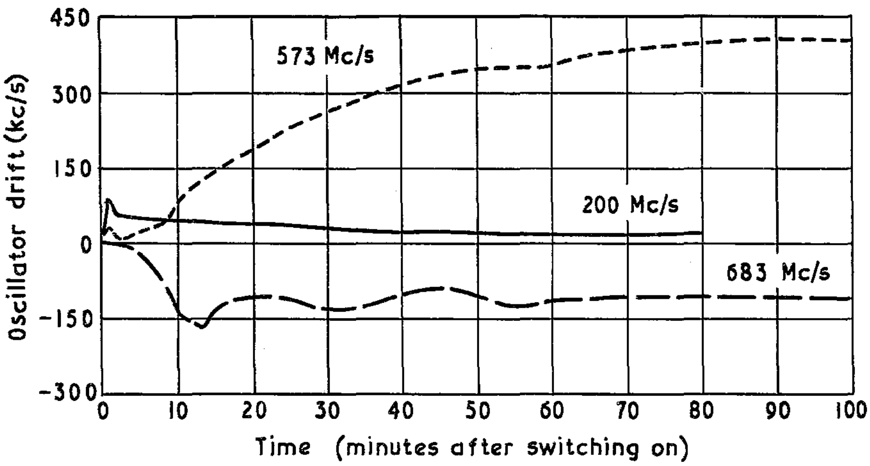


Fig. 16 - Tuner 1. Oscillator Drift.

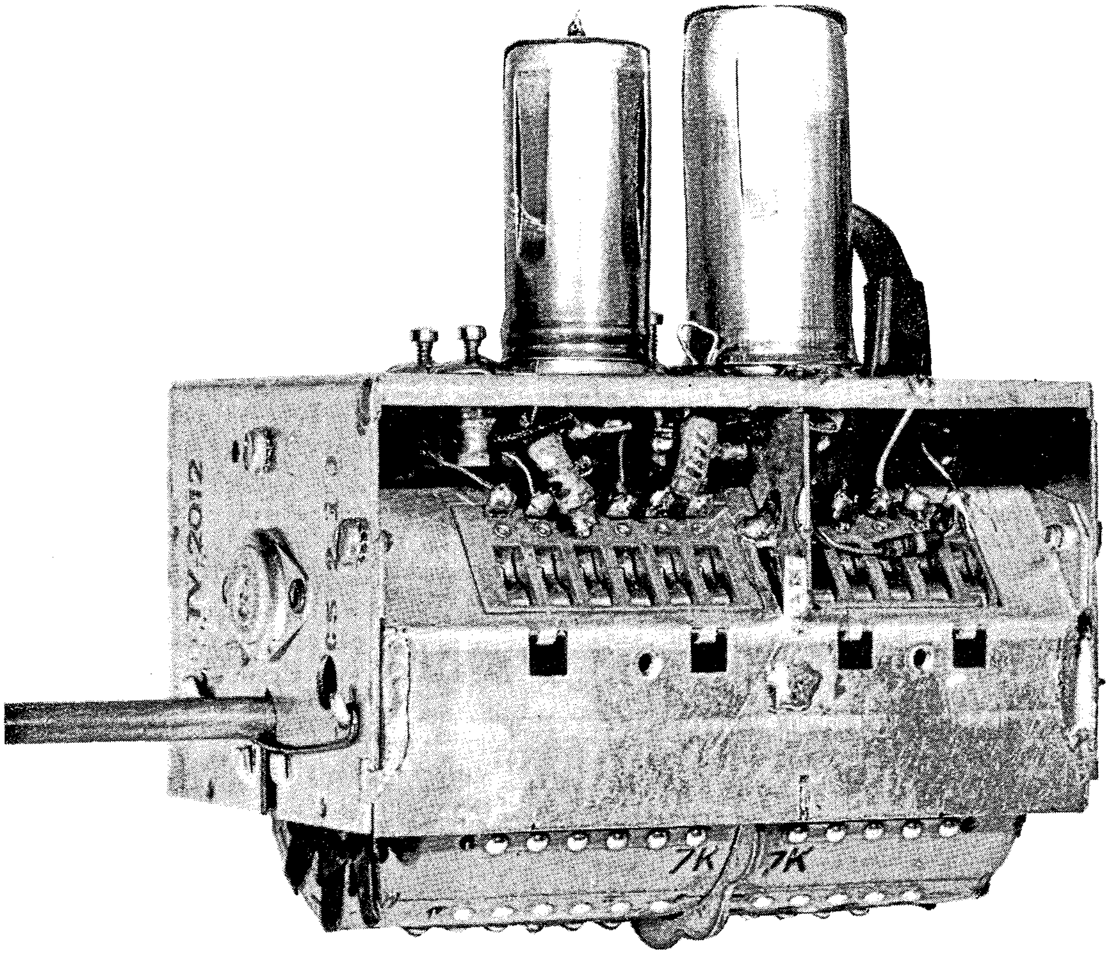
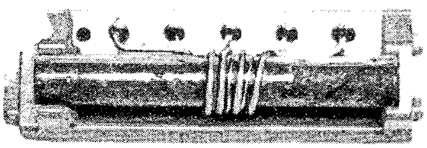
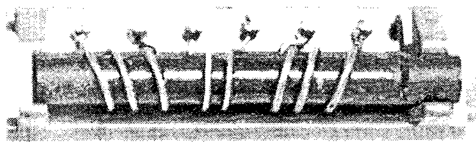


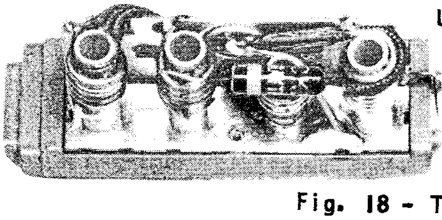
Fig. 17 - Tuner 2.

V.H.F. strips





U.H.F. strips



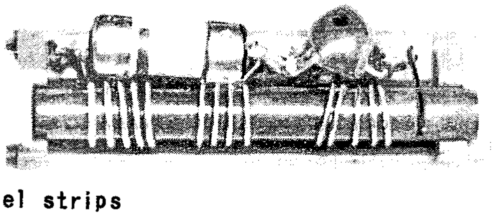


Fig. 18 - Tuner 2, channel strips

3.1.2. Tuner 2 (Figs. 17 - 20).

This is a twelve-position turret tuner; originally designed for v.h.f. only, u.h.f. reception is achieved by replacing the strips intended for v.h.f. channels with special u.h.f. strips. The strip for each channel is in two separate sections, as shown in Fig. 18. The price of these strips in the United States in 1953 was $5 per channel. The circuit diagram is shown in Fig. 19.

When used for v.h.f. reception, the circuit consists of cascode signal-frequency amplifier and a double triode used as an oscillator and triode mixer. In some models incorporating this turret the double triode is replaced by a triode-pentode.

When a u.h.f. strip is in use the circuit consists of two signal-frequency tuned circuits, followed by a crystal diode mixer. The i.f. output of the mixer is amplified by the double triode cascode and by the triode which is normally used as a mixer for v.h.f. reception. The oscillator triode is tuned to a frequency in the v.h.f. band, a second crystal diode being used to generate harmonics; a pre-set circuit selects the appropriate harmonic for the u.h.f. channel required. The unit tested was designed for an output frequency of 21·25 Mc/s (sound carrier) but units are also available for an output frequency of 41·25 Mc/s (sound carrier) in which the mixer valve is a triode-pentode; this gives a better performance than a triode when the i.f. is close to the lowest signal frequency, as it is, for instance, when receiving Channel 2.

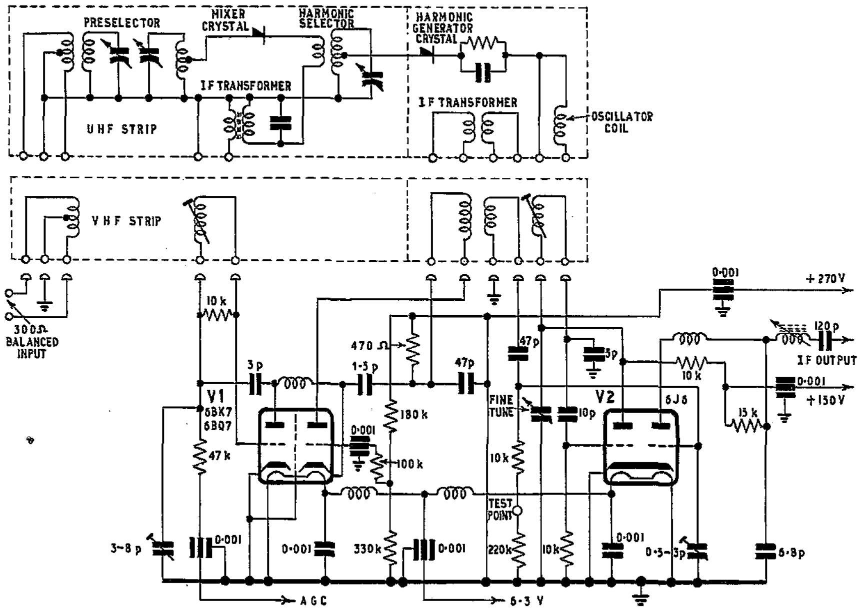


Fig. 19 - Tuner 2. Circuit Diagram.

Size:	5 in. (neglecting drive spindle) $\times 3\frac{1}{2}$ in. $\times 5\frac{1}{2}$ in. (13 cm × 9 cm × 14 cm)
Aerial input impedance:	300 ohms
Noise factor:	11 dB at 201 Mc/s > 19 dB at 550 Mc/s

Conversion gain:	The voltage gain was measured between the input terminals and the grid of the i.f. amplifier valve following the unit. Voltage gain 10 at 201 Mc/s " " 20 at 550 Mc/s
Overall bandwidth: (for loss of 6 dB)	8·5 Mc/s at 201 Mc/s 7·5 Mc/s at 550 Mc/s
Valves:	6BQ7 Cascode amplifier 6J6 Oscillator and mixer on v.h.f., or Oscillator and i.f. amplifier on u.h.f. CK710 Germanium diode mixer IN60 Germanium diode harmonic generator

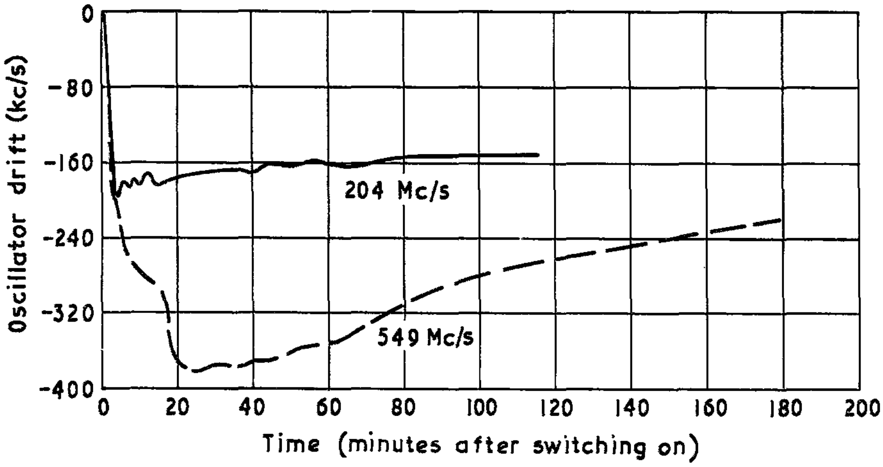


Fig. 20 - Tuner 2. Oscillator Drift.

4. GENERAL DISCUSSION

4.1. Construction

The construction of the u.h.f. equipment tested is surprisingly similar to that used at very much lower frequencies. The wiring layout appears at first to show a disregard for stray impedances, but must in fact be the result of considerable development work; the manufacturer's setting-up instructions include such details as the bending and positioning of leads. The mechanical construction is somewhat flimsy by British standards, but results in models which can apparently be produced very cheaply, and at the same time give a good performance. The units were all tested in the condition in which they were received from the United States, no re-aligning being attempted.

4.2. Noise factor

The measured noise factors in the u.h.f. band range from 12 dB to more than 19 dB. The lower figure represents a considerable achievement for a mass-produced article; it is within 3 dB of the lowest noise factor obtainable without a signal-frequency amplifier, even if cost and the need to cover a wide frequency band are secondary considerations.

Valves such as the 6AJ4 and 6AM4 are now being developed in the United States for use as signal-frequency amplifiers at u.h.f. If success is achieved, the resulting improvement in noise factor (over that of the existing better type of converter or tuning unit) will probably be small; these low noise factors may then be achieved more easily.

It is of interest to note that the noise factor assumed by the United States Federal Communications Commission, in specifying the field strength required for a satisfactory u.h.f. service, is 15 dB. The FCC (in the Sixth Report and Order dated 14th April, 1952) proposes two grades of service:

Grade A: a quality acceptable to the median observer for at least 90% of the time at the best 70% of receiver locations.

Grade B: a quality acceptable to the median observer for at least 90% of the time at the best 50% of the locations.

The corresponding calculated field strengths for the u.h.f. band are based on the following assumptions:

Grade of service	Noise in 70Ω dB rel. 1 μV	Receiver noise factor, dB	Required signal/noise ratio, dB	Receiver line loss, dB	Effective length of aerial, dB (rel. 1m)	Terrain factor, dB	Time fading factor, dB	Total, dB rel. 1 μV/m
A	7	15	30	5	−8*	6	3	74 (i.e. 5 mV/m)
B	7	15	30	5	−3*	0	4	64 (i.e. 1·6 mV/m)

*These figures imply an aerial gain at 600 Mc/s of 8 dB in the Grade A service area, and a gain of 13 dB in the Grade B service area. At higher frequencies the gains must be proportionally greater. It is doubtful whether these gains (particularly the higher gains) can be achieved in practical conditions.

The FCC requirements in respect of noise factor are met by Tuner 1 up to the maximum frequency for which strips were available, namely 695 Mc/s; this would therefore be suitable for use in the fringe areas. Convertor 1 had a similar performance; the noise factor met the FCC requirements up to a frequency of 775 Mc/s. The other units would be suitable for use only in areas where the field strength is high.

4.3. Drift of oscillator frequency

If it is assumed that the receiver is tuned 5 minutes after switching on, the drift of the local oscillator is reasonable except in the case of Convertor 3. On current receivers a change in the tuning of 250 kc/s must be made to cause just perceptible degradation of detail on a test card. A change of 500 kc/s is necessary

to cause perceptible degradation of a normal picture.

The effect of frequency drift on reception of the sound programme would be serious were it not for the fact that inter-carrier sound reception is employed in American sets manufactured in the past three years.

In Great Britain, on the other hand, since the sound signal is amplitude modulated, re-tuning would be necessary. Improved stability of the local oscillator or automatic frequency control would be essential for satisfactory reception in the u.h.f. band, assuming that the existing standards are retained.

4.4. Local oscillator radiation

Although no attempt was made to measure the field strength of radiation from the local oscillator, it is of sufficient importance to warrant mention, since there may be consequent interference with nearby television receivers working in the same band.

Radiation of the local oscillator tends to increase as the frequency increases. In the case of some early u.h.f. convertors used in the United States the field strength at a distance of 100 ft (30 m) and at a height of 30 ft (9 m) (the standard distances adopted for this test in the United States), was as high as 10 mV/m. No regulation limiting the field strength has been made by the FCC, but the industry is voluntarily attempting to achieve values not exceeding 50 μV/m in Channels 2-6, 150 μV/m in Channels 7-13, and 500 μV/m in Channels 14-83.

From the manufacturer's figures for Tuner 1 given in the Appendix, it is seen that these aims are achieved in the v.h.f. band; in the u.h.f. band, a field strength of approximately 2 mV/m is given. The figures "with shield" are within the limits stated above, but this refers to an auxiliary shield, covering the oscillator valve and the "fine tuning" slug, not supplied with the tuner.

The FCC had this source of trouble in mind when the frequency allocation plan was made. It is proposed to adopt a standard intermediate frequency of 41·25 Mc/s (sound carrier) in the United States, in which case radiation will fall in the seventh channel above or below the tuned channel. For this reason it is proposed to separate u.h.f. stations operating 7 channels apart by at least 60 miles (97 km). This allocation principle was adopted because it was expected that satisfactory suppression of local oscillator radiation might not be possible for a considerable time. Although the protection afforded by this forethought may ultimately be achieved, it will not be realised while convertors and intermediate frequencies other than 41·25 Mc/s are in common use.

5. CONCLUSIONS

The performance of the best continuously tunable and the best switched units tested is extremely good, remembering that the selling price is moderate; the noise factor is low and the gain adequate. The drift of the local oscillator is sufficiently low when the sound signal is frequency modulated and inter-carrier reception is used. Some improvement in this respect is desirable if the same units are to be used for a television service in which the sound signal is amplitude modulated.

APPENDIX

MANUFACTURER'S PERFORMANCE FIGURES FOR TUNER 1

V.H.F. Performance

Channel No.	Centre freq. in Mc/s	Noise factor dB	Voltage gain*	V.S.W.R. Input 300 ohms	Image rejection dB	I.F. rejection, dB, Input 300 ohms: I.F. = 43·5 Mc/s	I.F. rejection, dB, Input 300 ohms: I.F. = 45·7 Mc/s	Oscillator radiation in μV/m at 100 ft (30 m): without shield	Oscillator radiation in μV/m at 100 ft (30 m): with shield**
2	57	3·7	80	2·36	59·1	80	66	30	5
3	63	4·0	83	2·48	60	90	72		
4	69	4·5	77	2·06	59·5	90	79	32·1	5
5	79	4·6	95	2·82	57·3	90	88		
6	85	5·1	95	2·25	57·4	90	90	48·1	5
7	177	6·7	67	1·83	75·2	90	90	165	25
8	183	6·9	55	1·59	78	90	90		
9	189	6·6	55	1·66	75·9	90	90		
10	195	6·7	54	1·85	78·5	90	90	101·5	23·7
11	201	6·6	50	2·62	70·7	90	90		
12	207	6·6	51	2·73	78·8	90	90		
13	213	6·4	83	2·11	72·5	90	90	123·2	30·5

U.H.F. Performance

Chan. No.	Centre freq. in Mc/s	Noise factor dB	Voltage gain*	V.S.W.R. Input 300 ohms	V.S.W.R. Input 72 ohms	R.F. bandwidth (for 3 dB) Mc/s	Image rejection dB	I.F. rejection in dB: Input 300 ohms	I.F. rejection in dB: Input 72 ohms	Oscillator radiation in μV/m at 100 ft (30 m): without shield	Oscillator radiation in μV/m at 100 ft (30 m): with shield**
14	473	12·5	–	1·41	1·18	9	47·2	90	59·8		
19	503	13	10	1·34	1·22	9	46	90	60·6	1530	161
27	551	12·3		1·33	1·16	11	47·6	90	60·6		
35	599	13·7		1·34	1·27	11	36·5	90	60·1	1495	414
44	653	13·1		1·63	1·22	11	38·7	90	60·2		
52	701	15·6	7·8	1·7	1·25	9	50·9	90	62·2	2008	559
60	749	15·6		1·83	1·31	6	42·8	90	62·4		
69	803	16·2	8·7	1·74	1·17	8	42·9	90	63·0	1092	218
77	851	15·4		1·71	1·36	9	58·4	90	65·0		
83	887	16·4	5·3	1·2	1·22	8	50·3	90	62·1	2880	212

* These voltage gains are with reference to the grid of the first i.f. amplifier in the main receiver.

** This refers to an auxiliary shield covering the oscillator valve and the "fine tuning" slug; it is not used in current models.

Oscillator Drift

Channel No.	Nominal oscillator freq. Mc/s	Drift in kc/s after stated minutes from switching on: 0·5 min.	2·5 min.	5·0 min.	10 min.	20 min.	40 min.
3	107	0	+25 kc/s	+40 kc/s	+40 kc/s	+40 kc/s	+41 kc/s
9	233	0	+40 kc/s	+80 kc/s	+110 kc/s	+110 kc/s	+110 kc/s
15	523	0	–10 kc/s	+40 kc/s	+80 kc/s	+100 kc/s	+110 kc/s
51	709	0	–90 kc/s	–140 kc/s	–160 kc/s	–160 kc/s	–160 kc/s
78	901	0	–350 kc/s	–360 kc/s	–375 kc/s	–440 kc/s	–440 kc/s

Note: For channels above 830 Mc/s, a bimetal strip is placed near the oscillator trimmer capacity for temperature compensation.